Small-scale Forestry (2010) 9:317–329
DOI 10.1007/s11842-010-9118-y

RESEARCH PAPER

Economic Valuation of a Tamarind (*Tamarindus indica* L.) Production System: Green Money from Drylands of Eastern Uganda

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Accepted: 7 May 2010 / Published online: 11 June 2010

Abstract Tamarind (*Tamarindus indica*) is a valuable tree species Uganda and elsewhere in semi-arid Africa—for fruit, timber, leaves and shade—but like other indigenous species has been subject to decline in recent years. The success of steps to assist natural regeneration and rehabilitation will depend on the net financial benefits to the rural households, hence there is a need for improved financial information on the costs and returns of growing tamarind trees. This paper compares the financial performance of *T. indica* production in the open woodland and cropland areas in Uganda. Household surveys were carried out in Kamuli and Kaliro districts in eastern Uganda from July 2004 to February 2005. The estimated mean production of *T. indica* was 127 and 84 kg/ha/year from open woodland and cropland areas, respectively, a statistically significant difference. The net present value from *T. indica* products was US$ 893/ha in woodland and US$ 684/ha in cropland. In terms of foreign export earnings, *T. indica* juice from woodland and cropland was estimated to generate US$ 0.03/ha and US$ 0.02/ha, respectively. Returns from alternative land-use activities of agricultural cropping were highest for maize and lowest for finger millet in both open woodland and cropland sites. Sensitivity analysis revealed that an increase in the real discount rate from 9.86%

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(base case) to 15% decreases the financial NPVs of both the open woodland and cropland areas by 24%.

Keywords Desertification · Rural livelihood · Financial analysis · Fruit production

Introduction

Land degradation is one of the most serious social, economic and environmental problems confronting human needs today, with direct dire consequences for the livelihoods of the poor (Gregersen and Contreras 1992; FAO 2004). In Africa, human livelihoods revolve around direct dependence on productivity of the land. However, in many instances the ability of the land to support livelihoods has long been reduced by varying degrees of land degradation caused by increasing human pressure on the resource through overgrazing, over-cultivation, drought, deforestation and other causes linked to acute poverty (MoFPED 2003). In many places, previously fertile farmland has become so badly damaged to be in desert-like condition (Nabalegwa et al. 2007).

In Uganda, a large proportion of the country is covered by semi-arid landscape which is increasingly under threat from desertification due to various climatic factors and human activities (MWLE 2002). Further degradation of these already fragile dryland areas is causing serious consequences on the livelihoods of millions of its inhabitants, with some being forced to abandon them altogether.

Tamarind is a multi-purpose tropical tree belonging to the Fabaceae family (Caesalpinioideae sub-family), which is indigenous to tropical Africa and India. Tamarind occurs widely throughout tropical Africa, where it is frequently planted as a shade tree (Akinnifesi et al. 2008). The tamarind tree is found both on farms and in the wild. Ecologically, it combines well with cereal crops.

Tamarind regenerates well, and has traditionally been protected during bush clearing by farmers The trees on farms were initially in the wild but after clearing land for farming, they were retained as boundary markers, contour hedges or scattered on cropland. Some individual trees date back more than 60 years (ICRAF-ICA 2005). Tamarind produces multiple products that support the livelihoods of many rural people (Gunasena and Hughes 2000; ICRAF-ICA 2005). The wood has high hardness and durability, and is used for many purposes, including making furniture and mortars and for construction. The leaves and fruit are used for medicinal purposes, including treatment of bacterial meningitis. The fruit is used as a raw material for the manufacture of several products, including *T. indica* kernel powder, porridge, tartaric acid, tamarind juice concentrate, jam, syrup, candy, champoy, local wine and fodder for livestock (Gunasena and Hughes 2000).

Tarimand tree populations have been subject to increased pressure from agriculture, drought and parasitism in recent years and have been predicted to decline further in coming years (Coronel 1991; Shackelton et al. 2000; IFAD 2000; Gunasena and Hughes 2000). Despite its multi-purpose importance, most of the *Tamarindus indica* trees in Uganda have continued to be harvested indiscriminately

from the wild. Tamarind trees are being destroyed for charcoal production, and to create land for agricultural expansion in semi-arid woodlands. Attempts by the government of Uganda and NGOs to promote the domestication and hence the survival of tamarind trees—as well as other indigenous tree species including *Vitellaria nilotica* and *Prunus africana*—have achieved minimal success. However, there is increasing recognition that the solution to this problem lies in recognition of the economic value of tamarind production systems in both cropland and open woodland areas.

Recently, steps have been taken to close degraded forests to assist natural regeneration and rehabilitation. However, the sustainability of this management practice will largely depend on the net financial benefits to the rural households (Shackelton et al. 2000; IFAD 2000). In addition, sustainable forest management and planning requires data on both production and financial value of the resource. Therefore, there is a need for information on marketing and product prices of *T. Indica* in the drylands of Uganda. Relatively little research has been undertaken on the financial value of this species. The objective of this study was to determine the costs and returns associated with production and utilization of *T. indica* in open woodland as compared to cropland areas in Uganda.

The Physiography and Climate of the Study Area

The study was carried out in Kaliro and Kamuli districts in eastern Uganda. The area has a semi-arid continental climate with an average annual rainfall of 615 mm/year with extreme values of 290 and 900 mm mostly received between November and April, with marked dry periods in of June–July and October. Annual temperatures range from a minimum of 10°–12°C, to a maximum of 24°–32°C. The open woodland (site I) is located in Kaliro and the cropland (site II) is in Kamuli district.

The study area is generally flat but interrupted by undulating plains. The soils of both study sites are developed on lime-rich parent material, with ground surfaces that have been incised strongly by rill and gully erosion. Generally, the soils range from black loam in the low-lying marshland to less fertile reddish brown lateritic soil, especially on hilltops. The soils are slightly acidic (pH in water 5.7–6.1), and are low in organic carbon (4–8 g/kg), total nitrogen (0.1–0.3 g/kg) and exchangeable bases (MAAIF 2001).

The population density is about 230 persons/km^2, and the population growth rate is 2.3% (UBOS 2004). Subsistence agriculture is the major economic activity, employing about 84% of the population. The bulk of agricultural production is from manually cultivated rain-fed crops. Intercropping is a prevalent practice (MAAIF 2001). The vegetation of the study area is largely dominated by *Acacia etbiaca* and *Euclea shimperi*. The understorey vegetation comprises a highly diverse assemblage of grasses and herbs, most of which are palatable for livestock. Agricultural crops grown include cassava, maize and sweet potatoes; however, the crop yields are low (e.g., maize yields 500 kg/ha), with great variability depending on rainfall and location. The per capita arable land has progressively decreased from 0.36 ha in 1970 to 0.24 ha in 2000 (UBOS 2004).

Research Method

Data Collection

To estimate fruit yield of each site, given the limited research time and resources, 16 permanent square sample plots of 2,500 m^2 each were selected per site. A list of *T. indica* trees with a minimum of 10 cm diameter at breast height (dbh) was established for each plot and used as a sampling frame. The trees were grouped into three classes by diameter range taking their maximum and minimum diameter into account, and a total of 96 trees was selected using stratified random sampling. Each tree in the sample was marked with a permanent metallic plate bearing an identification number and was mapped using a GPS for later reference. The dbh, tree height (measured with a hypsometer) and crown diameter of sampled trees were recorded. The average diameter of the 96 trees was 25.5 cm (standard deviation 8.0 cm), average height 6.5 m (standard deviation 1.3 m), and average crown diameter 5.5 m (standard deviation 1.6 m).

Tamarindus indica fruit were collected from sample trees during the harvesting season between July 2004 and February 2005, with an average collection interval of 18 days. The collected fruit were weighed, dried, graded and weighed again for each sample tree. Six grades of fruit were used, designated T1, T2, T3, and T4-special for export standards, and T4 and T5 for domestic product. The grading—based on size, colour, weight and taste—was conducted in the town of Jinja.

For each site, the yield of every sample tree was used in estimating the yield of all trees in that particular diameter class. The overall mean yields per tree and per plot were then estimated from these per-diameter-class values. All fruit produced by sample trees were harvested manually. The fruit of individual trees was counted and the fruit harvest per tree was weighed with and without the outer pulp. Average fruit production per tree over the harvesting season was projected at the field level on the basis of average tree densities, tree productivity and field size obtained in the sample of fields. The yield of juice in dry kernels was assumed to be 20%.

To estimate the annual fodder production of the open woodland site, three square sub-plots each of 1 m^2 size were randomly sampled from each of the 16 observation plots. From each of these sub-plots, fodder was cut and weighed. The annual fodder harvest in kilograms per hectare was then estimated by scaling up the sample plot yields. The resulting values were corrected to account for the tree basal area (7.52 m^2/ha) due to the fact the area was not entirely covered with fodder.

A household survey was carried out in both study sites with the help of complete lists of households that deliberately planted tamarind on their cropland, obtained from District Agricultural Officers of Kamuli and Kaliro districts from July 2004 to February 2005. In order to estimate the input and output quantities of crop production, a semi-structured questionnaire was developed, tested and administered to farm household respondents. A total of 104 households (30% sampling intensity) was selected using systematic random sampling and the response rate was 82%.

Base year (2002–2003) prices of *T. indica* fruit and the costs of processing and trading each quality grade of the product were obtained from Ministry of Trade, Industry and Tourism. The price per 100 kg of fruit was considered as the daily

wage for collecting mature fruit from the forest. Market prices of major crops and livestock were obtained from the District Agricultural Office. In cases where the *T. indica* trees were located in an open woodland, the foregone alternative wood consumption was calculated assuming a total wood volume of 22 m^3/ha for site I and 21.3 m^3/ha for site II (following MWLE 2002). The market prices for fodder and agricultural crops were obtained through direct interviews with local people.

Data Analysis

In the financial investment analysis, many benefits of trees and shrubs are usually not included because they are difficult to quantify and are not expressed in cash terms (Rommelse 2000). In reality, however, cash impact is the only yardstick farmers use to judge a possible investment. Fischler and Wortmann (1999) have linked this revelation to the farmer's motive of trying to maximize profits using the scarce factors of production available. Estimating the financial benefits of tamarind production options was complicated by the long maturity cycle. Moreover, in this study and previous studies (e.g. that of Kaizzi et al. 2002) many benefits of tamarind trees were not included because they are difficult to quantify and are not expressed in monetary terms.

In this study, a financial analysis of costs and returns was conducted by taking the viewpoint of a private enterprise using market prices for valuing project (tamarind production) cash flows. The revenue and costs predicted to occur over time were discounted to make the project effects comparable. Project calculations were based on nominal values, i.e. referring to nominal prices including inflation, where a nominal discount rate was applied and the interest rate was calculated by applying Eq. 1 (from Boardman et al. 2001):

$$r = \frac{i - \pi}{1 + \pi} \tag{1}$$

where r is the real discount rate, i is the nominal discount rate, and π is the inflation rate.

For general investment analysis, it is advisable to use the current consumer price index (CPI) as an estimate for inflation. However, this estimate reflects the general development of all consumer prices, which might overestimate or underestimate the price movement of the specific project outputs. With regard to this study, the geometric mean of some general inflation data was used as a proxy and calculated according to Eq. 2 (following Jacobs 1997), where p is the price index and the subscript determines the specific year:

$$\pi = \left[\frac{p_2}{p_1} x \frac{p_3}{p_2} x \frac{p_n}{p_{n-1}}\right]^{\frac{1}{n-1}} - 1 \tag{2}$$

The average inflation rate of $\pi \cong 2.4\%$ and a nominal interest rate of 12.5% was determined based on the data given in Table 1. Consequently, the real interest rate r was 9.86%.

Table 1 Price index and interest rates in Uganda, 1998–1999 to 2004–2005

Year	Price index	Lending interest rate
1998–1999	98.2	10.5–12
1999–2000	102.8	10.5–13
2000–2001	109.2	10.5–13.5
2001–2002	103.5	10.5–15
2002–2003	96	7.5–13
2004–2005	110.5	7.5–13

Source MAAIF (2006)

The net present value (NPV) of each investment option measured in US$ per hectare is derived as:

$$\mathrm{NPV} = \sum_{t=0}^{T} \left[(B_t - C_t)(1+r)^{-t} \right] \quad (3)$$

where B_t = the revenue in year t (US$/ha), C_t = the total cost at time t (US$/ha), r = real discount rate, and t = time in years ($t = 0, 1, 2, 2, \ldots, n$).

Tamarind trees found in Uganda yield fruit once in a year, the maturity period of tamarind crop is 15–20 years, and trees have a productive life span of about two harvesting cycles. According to this schedule, collection of mature fruit is conducted during five consecutive years and the first 5-year period commences when trees are aged 15 years, followed by a resting period of 3 years, which is necessary for the tree to rejuvenate. This cycle repeated twice meaning the crop is allowed to grow and harvested twice and with diminishing yield the crop is finally clear felled (at the age of 28 years) and used as timber. Benefits and costs during the resting periods were assumed to be zero.

Tamarind production costs in the analysis included wages for fruits collectors, other harvesting costs, the cost of grading and processing of fruits, storage cost, transport cost, fees of collection agents, local government levy charges, and overhead expenses such as utility bills. Comparison of the open woodland with agricultural crop production was also made by calculating the NPV of cropland of farm households in the study area. Finally, a sensitivity analysis was made to determine the impact on NPV of changes in discount rate, tamarind and crop yields, and input and output prices.

Findings from the Financial Analysis

Of the tamarind juice grades mentioned above, four are export quality grades (T1 to T4-special) and two are domestic product grades (T4 and T5). Table 2 indicates that the mean annual yield of fruit and the quality grades of juice from the open woodland site were larger than for the cropland site on both a per tree and a per hectare basis. This difference in yield could be attributed to the differences in tree density and management systems.

Table 2 Annual fruit and fodder production from *T. indica* tree resources

Products	Site I		Site II		*T* statistic	Prob. (2-tailed)
	Mean	SE	Mean	SE		
Trees/plot ($N_1 = N_2 = 16$)	63.188	6.771	54.688	5.849	0.950	0.350
T. indica fruit (kg/tree) ($n_2 = n_2 = 3$)						
T_1	502.827	43.797	386.486	32.052	2.144	0.040*
T_2	64.139	5.703	49.272	5.174	1.931	0.063
T_3	6.467	1.349	7.175	0.944	−0.430	0.670
T_4-special	1.310	0.577	0.000	0.000	2.269	0.031*
T_4	115.565	11.515	107.977	9.153	0.516	0.610
T_5	171.017	20.683	107.305	16.331	2.418	0.022*
T. indica fruits (kg/ha)	119.261	9.194	108.865	6.604	0.918	0.366
Regular	127.09		84.54			
Export qualities	47.38		35.97			
$G_4 + G_5$	73.36		47.28			
Impurities	6.35		1.29			
Fodder (kg/m^2/year)	0.266	0.012	Free grazing			

n = number of sample trees in a plot, n^* = number of sample sub-plots in a sample plot, N = number of sample plots; SE = standard error

The major agricultural crops grown by sample farm households were finger millet, maize and soybean. These crops covered about 99 and 91% of the croplands and open woodland, respectively. This finding contrasts with the common farming practices in open woodlands, however, this was due to the current government program for Modernization of Agriculture and optimal land utilization where intensive agriculture is being promoted even in traditionally open woodlands with sparse agricultural activities. There was no significant difference between the average amounts of seed used per hectare of land for all crop types grown, and sample households did not use commercial fertilizer. Crop physical yield was highest for maize and lowest for finger millet in both sites. Crop residuals equivalent of 1.2 and 1.48 m^3 of fuelwood could be produced from 1 ha of open woodland and cropland, respectively. The average market prices of inputs and outputs used in the calculation are reported in Table 3.

Financial Analysis of Alternative *T. indica* Production Outputs

A comparison is made of the agricultural productivity and economic viability of managing open woodland with agricultural crop production, in terms of net present value. Following the base year (2002–2003) market conditions with a real discount rate of 9.86%, the NPV for *T. indica* fruits was US$ 913/ha in open woodland and US$ 683/ha in cropland (Table 4). The difference is due to higher financial net returns from both *T. indica* fruit and fodder production in open woodland. The NPV from *T. indica* fruit accounts for only 4.65% of the total site NPV. The remaining larger shares are attributed to the financial returns from fodder harvesting and free

Table 3 Physical quantities of inputs and outputs of agricultural crop production

Input/outputs	Site I ($n = 50$)		Site II ($n = 54$)		t-value (2-tailed)	P-value ($df = 102$)
	Mean	SE	Mean	SE		
(a) Input						
Household cropland (ha)	2.49	0.16	1.95	0.18	2.23	0.03*
Seed (quintals/ha)						
Finger millet	0.31	0.03	0.32	0.03	−0.22	0.83
Sorghum	0.18	0.02	0.17	0.02	0.41	0.68
Maize	0.35	0.04	0.48	0.13	−0.91	0.36
Soybean	0.27	0.02	0.29	0.04	−0.51	0.61
Fertilizer in quintal/ha	NA		NA		NA	
Cattle (no./HH)	2		2			
(b) Output						
Crop (quintal/ha)						
Finger millet	1.31	0.15	0.79	0.09	2.83	0.01*
Sorghum	2.74	0.22	2.91	0.28	−0.48	0.64
Maize	3.81	0.72	4.30	0.55	−0.56	0.58
Soybean	1.39	0.17	1.45	0.29	−0.17	0.86
Bean			1.83	0.65		
Crop residuals for fuel (m^3/ha)	1.20			1.48		

n = number of sample households, * mean values of Site I and Site II are significantly different, 1 quintal = 100 kg

SE standard error

Table 4 Net present value of *T. indica* fruit (US$)

Product	PVB		PVC		NPV	
	Site I	Site II	Site I	Site II	Site I	Site II
Export quality	334	242	223	165	110	77
$T_4 + T_5$	200	123	268	168	−68	−45
Fodder harvest	871	NA	0	NA	871	NA
Free grazing	NA	654	NA	0	NA	654
Total	1,405	1,018	492	333	914	685

Exchange rate: US $1 = UShs. 1960

grazing. The reason for this was that fruit production generates financial costs whereas fodder harvesting and free grazing involves only free family labour, for which no opportunity cost has been allocated (due to unavailability of paid employment for the farmers).

The present value of costs per hectare (PVC) for producing T4 + T5 *T. indica* fruits was larger than the present value of benefits (PVB). With respect to export

Table 5 Present value of foreign exchange (US$/ha) from *T. indica* fruit, open woodland

Export quality *T. indica* fruit	Site I		Site II	
	Annual revenue	Present value	Annual revenue	Present value
T1	31	250	22	152
T2	4	23	2	23
T3	1	3	0	0
T4-special	25	137	18	112
Total	60	413	42	288

quality grades, a positive present value is estimated, accounted for 13 and 10% of the total financial NPV of open woodland and cropland, respectively.

Distribution of Income from *T. indica* Tree in Open Woodland and Cropland

The annual revenue per hectare of open woodland site was found to be 1.39 times that from cropland site (Table 5). The annual revenue from *T. indica* fruit production of open woodland accounted for 45 and 43% of the total revenue. The remaining proportions were generated by fodder harvesting and free grazing, respectively.

Rural households living near the study sites earned most of their revenue from fodder harvesting. This population group also derives income in the form of wages for collecting *T. indica* fruit. These revenues accounted for about 43 and 42% of the total *T. indica* fruit revenue per hectare in open woodland and cropland, respectively. Thus, referring to the total annual revenue per hectare of open woodland, 74% in woodland and 75% in cropland were earned by rural people near the study sites.

About 8% of the annual *T. indica* fruit revenue per hectare was distributed as wages to urban poor women engaged in grading and processing *T. indica* juice. The profit for *T. indica* juice trading firms accounted for 8 and 9% of the annual *T. indica* fruit revenue per hectare in the open woodland and cropland sites, respectively. The remaining proportion of annual revenue was attributed to other groups of the society that provide their factor input to the production and trading of *T. indica* fruit in the form of services including transport and labour. Annual foreign exchange gross revenues of US$ 60/ha and US$ 42/ha were obtained from the production and export of *T. indica* juice from the open woodlands and cropland, respectively. About 58% of the foreign exchange earnings could be assigned to T1 fruit in open woodland and about 53% in cropland (Table 6).

Sensitivity Analysis

Sensitivity analysis was conducted to determine the impact on NPV of changes in parameter values. An increase in the real discount rate from 9.86 (base case) to 15% was found to decrease the financial NPVs of the open woodland and cropland site by 24%.

Table 6 Distribution of revenues from *T. indica* open woodland to factor inputs (US$/ha)

Product	Site I		Site II	
	Annual	Present value	Annual	Present value
Collectors wage	32	229	22	153
Fodder consumption	91	871	68	654
Total households income	123	1,101	90	806
Profit margin	6	42	4	32
Processors and graders (wage)	6	42	4	28
Income of other groups[a]	31	220	22	152
Revenue from *T. indica* juice	75	534	52	365
Total revenue	166	1,405	120	1,018

[a] Transport charges, wages to employees and other expenses in trading *T. indica* juice

Table 7 Effect of changes in yield and prices on NPV in US$/ha/year

Parameter	NPV							
Change in parameter	Site I +50%	II	I +20%	II	I −20%	II	I −50%	II
Base year	5	3	5	3	5	3	5	3
Prices of all inputs	668	519	816	619	1,012	752	1,159	852
Wage for collectors	609	868	655	960	716	1,028	762	762
Transport costs	870	655	896	673	931	698	958	716
T. indica yield	5	4	5	3	5	3	4	3
Price of *T. indica* juice	1,181	868	1,021	758	807	612	647	503
Price of fodder	1,349	1,012	1,088	816	739	555	478	359
Fodder yield	7	5	5	4	4	3	2	2
Total yield	7	5	5	4	4	3	2	2
Price of all output	1,616	1,195	1,195	889	633	482	211	176

The financial NPVs of both sites are highly sensitive to changes in prices of all output (Table 7), total yield, yield of fodder, price of fodder, and prices of all inputs, but less sensitive to changes in price of *T. indica* juice, fruits yield, transport cost and wage rate for collectors. The change of Tamarind products price has the greatest relative effect on financial returns. A 20% reduction in prices of all forest products would result in 76.9 and 74.3% reductions in financial NPV of open woodlands and cropland, respectively. Of this reduction in NPV, 29.2 and 26.6% are due to the reduction in market price of *T. indica* fruit fodder, respectively.

Changes in prices of inputs of *T. indica* fruit production have little effect on NPV of open woodland due mainly the fact that it is only *T. indica* fruit production that generates financial costs whereas fodder harvesting and grazing involve free family labour. As a result, an increase in the wage for collectors of *T. indica* fruit by 20%,

for example, will decrease the NPV by only 5.0% in open woodland and by 4.5% in cropland. An increase in transport costs by 20% would result in a reduction of NPV by only 1.9% in open woodland and 1.8% in cropland. If the prices of all inputs of *T. indica* fruit production increase by 20%, the financial return per hectare will decease by only 10.8% in open woodland and 9.7% in cropland. On the other hand, the reduction of yield of *T. indica* fruit has little effect on predicted financial return for both sites. A 28% reduction in total yield of the non-wood forests products (fruits and fodder) would result in an equivalent 28% reduction in project NPV. However, of this change a reduction in yield of *T. indica* fruit would result only a 2.3% of reduction in NPV per hectare of each of the sites, the remaining 46.7% of reduction being due to the 28% reduction of yield of fodder.

Discussion

This study revealed that managing *T. indica* trees as a open woodland area and as cropland in Uganda could provide positive financial returns. The predicted monetary disadvantage based on forgone wood and crop production is lower than the net benefits from the current use of the open woodland. Moreover, the financial NPV of the *T. indica* fruit in open woodland is larger by US$ 23/ha than that of cropland.

Assuming a current amount of 330,000 ha of *T. indica* fruit open woodland in the project region (following Moyini and Muramira 2002), a typical 5-year harvesting cycle with 3 years of rest, and the fruit yield per hectare as in Table 2, the annual potential *T. indica* fruit yield of *T. indica* fruit forests in Uganda could range between 9.4 and 14.1 million kilograms. In terms of foreign exchange, the total *T. indica* fruit forest area could have a potential of generating 4.33–5.97 millions of US$/year through exporting *T. indica* juice, which would represent about 0.9–1.24% of the country's total export revenue of 482.7 million US$ in 2003–2004.

The largest share of revenue from the *T. indica* goes to the rural people who are the immediate decision-makers in the management of the open woodland. Moreover, because most people in rural areas of Uganda in general and the study site in particular live in poverty, a land use that favours the distribution of the larger share of income to these members of the society has to be encouraged. The income from open woodland in the study area can diversify the economic activity of rural households, thereby reducing risks associated with frequent crop and fodder failures due to recurring drought. Annual income from open woodland in Uganda is substantial, and these sites have higher *T. indica* density than cropping land. Tamarind production can diversify the economic activity of rural households in open woodlands and therefore lead to rural development through poverty reduction. Future research is needed about the conditions for sustainable management of *T. indica* fruit plantations, which not only have the potential to increase the benefits from fruit and fodder production, but also to reduce soil erosion and environmental degradation.

Conclusion

The present analysis showed that management of *T. indica* as a land-use activity both in open woodland and cropland has higher net returns than agricultural production. This is mainly due to a higher productivity of *T. indica* fruit and fodder production especially in the open woodland area. The major agricultural crops grown include sorghum, finger millet, maize, and soybean. There was no significant difference between the average amounts of seed used per hectare of land for all crop types grown, and sample households did not use commercial fertilizer.

Tamarind fruit production from the open woodland area was predicted to be 1.5 times as high as from the cropland sites. *T. indica* production in open woodland and cropland provide higher net financial returns than the nearby agricultural cropland. The greatest share of annual revenue from open woodland is earned by rural households in the form of wage for collecting *T. indica* fruit and using fodder for their livestock. However, the annual income of rural households from the open woodland is higher than from cropland. The potential foreign exchange earning from open woodland through the production and export of *T. indica* juice is higher for the open woodland than for cropland. The positive NPV of *T. indica* products from open woodlands and cropland is due to relatively high market prices and low costs of production of the export quality grades as compared to the domestically quality grades. Production and trading of *T. indica* juice would appear to be a profitable business for firms which want to engage in exporting the product.

Acknowledgment Funds to carry out this study were provided as a post-doctoral research grant to the second author by the Department of Economic Planning and Management, Gadjah Mada University, Yogyakarta, Indonesia.

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